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SUBDIVISION OF TECHNICAL SERVICES
BUREAU OF PHYSICAL RESEARCH

ENGINEERING RESEARCH FOR TRANSPORTATION

JANUARY 1968

STATE OF NEW YORK / DEPARTMENT OF TRANSPORTATION

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J. BURCH McMORRAN
COMMISSIONER

TO: J. Burch McMorran,
Commissioner of Transportation

FROM: George W. McAlpin,
Deputy Chief Engineer

In compliance with your request, I have reviewed the current status of transportation technology, and assessed the need for engineering research in this field. This report presents my findings and recommends actions required to establish within the Department a broadly based research organization that can progress programs encompassing the engineering needs of all modes of travel.

My understanding of the Department's total responsibilities for Statewide transportation suggests that engineering research is required as a support activity for every phase of our mission. Our current highway research program is productive and in balance with design and construction needs; a similar program is necessary for action on problems concerning other modes of travel. The total research program must produce facts that will permit management and engineering operations to determine worth and applicability of new technologies and innovations, to optimize the value of products and services, and to avoid the disaster of early obsolescence of capital equipment and facilities.

In my opinion, the recommended organizational concepts, staff requirements, and funding levels for mass transportation research are conservative, but appropriate for initiation of our efforts. With the anticipated support and cooperation of other public transportation agencies, a "go" program will be developed.

George W. McAlpin

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INTRODUCTION

Establishment of the State Department of Transportation--an agency with broad, comprehensive responsibilities for New York's transportation system--has required analysis of the current status of engineering technology as it applies to all modes of travel (automobiles, trucks, buses, railroads, subways, water vehicles, and planes). A portion of this analysis, the results of which are reported here, has been directed toward answering the following questions:

- In transportation, is engineering research needed?
- If the need exists, what are the functions of the engineering research organization?
- What research subjects should be undertaken?
- What level of funding is appropriate?
- Through what action can the Department of Transportation meet its engineering research responsibilities?

* * *

The term "Engineering Research" as used here denotes research, development, and experimental work on problems related to design, construction, maintenance, and operation of transportation equipment and facilities. In general, these may be characterized as vehicles, vehicle controls, roadbeds, and intermodal transfer facilities.

THE NEED FOR ENGINEERING RESEARCH

In government or industry, the need for engineering research must be critically and objectively reviewed. It must be shown that research will produce tangible results that are meaningful to efficient fulfillment of the organization's mission.

Industry's Experience

At the turn of the century, manufactured goods were in great demand. Industry devoted full energies to increasing the quantity of production; it did not institute supplemental research programs. Once a product or process was established, production rate was the sole concern -- contemplation of change was pronounced heresy.

History records that the prosperity of many industries of that period was short-lived. Management failed to recognize that progress means change; it had not established research activities to provide guidance for decision making.

The lessons of history prompt modern industrial management to turn to engineering research for accomplishment of one or more of the following objectives:

- To anticipate and prevent future problems.
- To cure existing problems.
- To reduce cost of a service or product, and assure economical operation and maintenance.
- To increase the utility of a service or product through modifications.
- To develop and use new services or products.
- To improve the quality of existing services or products.
- To bring about better standardization through quality assurance.
- To amass and disseminate technical information.

Today, industrial management recognizes engineering research as an essential activity. Product quality, cost, and market acceptance must be continuously re-appraised. New technologies and innovations must be examined to determine their worth and applicability. Scientific effort must attempt to reach beyond current horizons.

Decision-making today relies heavily on facts provided by research. Intuition has proved an unacceptable gamble in solving today's problems or projecting for the future.

The Department's Responsibilities

In broadest terms, the Department of Transportation has responsibilities for all aspects of transportation within the State. More specifically, it has three major missions:

- Design, construction, maintenance, and operation of the State Highway System.
- Development and continual updating of a comprehensive Plan for a Statewide Transportation System covering urban and rural needs, all modes of travel, and all subdivisions of government.
- Administration of the State Aid Program for Capital Improvements to mass transit and airport facilities.

These three Departmental missions individually and collectively involve engineering responsibilities that must be met by an aggressive research program.

The State Highway System. Responsibilities are essentially the same as previously assigned to the Department of Public Works. A 1955 study conducted by that Department conclusively showed an urgent, continuing need for a formal engineering research program. In 1958, the Bureau of Physical Research was activated to conduct this activity. This Bureau's technical contributions since then have resulted in major construction economies, improvements in performance, increased safety, and breakthroughs in engineering theories and procedures. The need for highway research,

suggested in 1955, has been fully demonstrated. Research is a continuing, essential element of the highway design, construction, and maintenance programs.

The Statewide Transportation System. Planning is a dynamic activity that must include a capability for response to change. The Plan must be continually reappraised and updated as technology advances; it must always be a projection fully taking into account conditions that will exist in the real world of tomorrow. Engineering research must be an integral part of this planning process.

In addition to these planning responsibilities, the Department, as focal point for the Statewide System, has an obligation to furnish leadership and direction in the development of engineering technology.

For highways, this obligation has been met by the Department's engineering research program. This program's results have contributed useful technology for design, construction, and maintenance of highways and streets in all towns, counties, and municipalities of the State, and has significantly guided manufacturing and supply industries in improvement of their products and processes.

For mass transit, the Department must provide a mechanism assuring that engineering problems that might be deterrents to development of the System are sought out and solved, and that the best of current technology is disseminated to all transportation agencies. Such a mechanism would include an engineering research program.

The State Aid Program for Capital Improvements. This work will focus on updating, extending, and/or replacing airports and mass transportation facilities. In administering this program, the Department must objectively examine each request for improvement funds to assure that it is compatible with the Statewide Transportation Plan, that specifics of the proposal will fulfill local transportation needs and objectives, and that engineering aspects of the project are sound in light of current technology. Tested experience from industry and the Department's highway program demonstrate that an effective engineering operation must include an aggressive research group who know the status of new developments that may soon be coming into production and service, and the probabilities for long-term advances and improvements possibly antiquating part or all of a proposed system.

FUNCTIONS OF ENGINEERING RESEARCH

Engineering research involves three functions, each of which is accountable for contributing improvements in products or services with a favorable cost-benefits ratio:

- Identifying and defining subjects that are researchable--that is, suitable and manageable for study.
- Conducting or progressing the experimental work.
- Disseminating research findings and aiding in their implementation.

Each of these functions is examined here individually and then in terms of operational activities: *Technical Management* and *Research Projects*.

Identifying Subjects for Research

Many of government's and industry's transportation research projects in progress will be non-productive, because their objectives are too generalized. Their subjects have not been narrowed, by specific problem statements, to manageable, technically realistic scopes. This lack of adequate definition of subject represents a major weakness of on-going programs.

A successful, productive research program depends largely upon generation of ideas for improvements from within operating units. Such ideas usually relate to problems observed or experienced by the operating staff. They are real and their solution almost always pays dividends. Preliminary screening of these ideas usually shows that at least 50 percent can be solved without undertaking research. The remaining 50 percent must be objectively analyzed from the standpoint of cost and time required for experimentation, likelihood of technical success, practicality of implementation, and benefits--both financial and service improvements.

Considerable effort is required in the analysis necessary to establish a worthwhile research problem. There are no shortcuts in moving from an idea for improvement to a project statement. Engineers knowledgeable in research procedures must consult with those from operating units who have firsthand data concerning the problem. The entire success of the research effort hinges on their ability to identify and define the research subject precisely.

Selection of projects to be included in on-going research programs requires establishment of priorities. All the basic data needed are included in the problem statements; judgments as to relative importance and urgency must be made by management in light of both short- and long-term objectives. In recognition of changes in objectives and in available technology, priorities of assignment must be periodically reviewed and programs realistically realigned.

Progressing the Experimental Work

Each research project problem statement must be formalized to the extent of developing a detailed Working Plan that further defines the objectives, scope, cost, and time requirements noted in the problem statement, and outlines procedures to be followed in advancing the experimentation and in submitting progress and final reports.

Transportation facilities present a broad spectrum of engineering problems. The research program will require the services of engineers and scientists from numerous disciplines. It is impractical to staff a single research group with personnel having the required special competencies for all possible types of projects. Contract or consulting services must be employed to advance the projects. Capable individual researchers and units exist today within many operating transportation agencies, in commercial research organizations, in universities, and in industry. Selection of the research unit to advance specific items of experimental work requires a careful matching of project objectives and unit capabilities.

As experimental work progresses, it must be periodically monitored to assure adherence to the Working Plan, and to evaluate the need for modifications or realignments.

Disseminating and Implementing Research Findings

There is no shortage of research findings relating to transportation technology. However, the mechanisms available for dissemination and implementation of this information are ineffective. Frequently, information either does not reach the engineers responsible for operation of transportation systems, or comes in forms not readily applicable to solution of their problems.

The portion of research findings actually utilized to improve current practices and procedures for design, construction, maintenance, and operations is discouragingly low. This waste of technology is a critical problem common to most fields of scientific endeavor. Minimizing this waste, and bridging the gap between experimentation and application, requires three activities:

- Searching all available published findings of technology for information useful in solving real-life problems.
- Analyzing these data as required to translate them from generalized information to solutions of specific local problems of pertinence to the organization.
- Disseminating these specific solutions to operating units and assisting with their implementation.

Technical Management and Research Projects

These three functions of engineering research (to identify, to progress, and to disseminate) may be considered to constitute two operational activities: Research Projects (second function) which concerns only progression of experimental work as previously described, and Technical Management (first and third functions), which will now be discussed.

The most essential assignments of the engineering research unit are to search out and identify subjects needing experimentation, and to examine, analyze, and disseminate research findings. These stimulate the flow of engineering problems from operating transportation agencies to scientific groups, and also the return of engi-

neering solutions. As "middlemen," the researchers must establish effective cooperation and liaison with both "operators" and "scientists." They must be able to translate and communicate in both practical and theoretical terminology. The Department needs a staff to manage this technical activity.

It should be noted that this does not require participation in experimental work. Staff requirements for Technical Management are not dependent upon whether the Department sponsors research projects--either in-house or by contract.

For highways, the Technical Management requirement is fulfilled by the current Physical Research staff. Due to the in-house relationship between this group and the engineers involved in highway design, construction, maintenance, and operations, effective liaison already has been established.

For mass transportation, the Department must establish a staff within the engineering research unit, for the Technical Management activities just described. This group must have competence in electrical, mechanical, and civil engineering as related to transportation, and must be knowledgeable in research procedures. Since the Department does not "operate" mass transportation facilities, a mechanism must be devised to assure that its research staff and engineers from the operating agencies have the opportunity to communicate freely and fully.

It is suggested that this required interchange between operations and research can be accomplished through the activities of a research advisory group consisting of representatives from the mass transportation operating organizations. This group would search for problems needing experimentation, assist in preparing statements of research needs, and advise on research priorities and other aspects of the program.

SUBJECTS FOR ENGINEERING RESEARCH

In the past few years, "hard research" in the engineering phases of transportation has paid invaluable dividends. Major improvements have been made in design, construction, and maintenance procedures, materials, equipment, and facilities. This great progress might suggest to those not directly involved in engineering activities that most of the "big" problems have been solved, that the benefits to be derived from engineering research have reached a plateau, that continuing effort need concern only refinement of established procedures. Such an impression is not substantiated by fact. The rapid development of science and technology coupled with the widespread demand for more effective, efficient, and economical products and services has detonated an engineering revolution; more than ever before, the engineering profession is urgently searching for new information that will assist in solving its problems.

Highways

A recent report, "Research Needs in Highway Transportation," tabulates nearly 1,000 subjects that merit research attention.* Many are stated in generalized terms, which after appropriate division and subdivision into specifically defined topics, would constitute 5,000 research projects.

In Appendix A, each project being progressed by the Department's Bureau of Physical Research is described and work being done by other agencies is discussed by subject areas— design of pavements and structures, safety, materials and construction practices, and soil mechanics and foundations.

A great deal of conceptual work has been done with regard to highways of the future. The "Century Expressway" envisioned by Cornell Aeronautical Laboratories would have special roadways with complete guidance control for automobiles traveling at 100 mph. The General Motors "Autoline" provides guidance by embedding a cable in

*Prepared by Bertram D. Tallamy Associates and Wilbur Smith and Associates, under National Cooperative Highway Research Project Contract for the Highway Research Board of the National Academy of Sciences-National Academy of Engineering.

the pavement with corresponding electronic sensors in the vehicle. Mini-autos may increase highway and street traffic capacity and reduce parking problems; if electric-powered, they would have no air-pollutant emission and would be almost noiseless.

Numerous projects are exploring the field of driver communications -- electronic systems that evaluate highway traffic conditions and advise the driver concerning proper actions. For example, the automatic passing aid system would sense the location and speed of opposing vehicles on a two-lane rural highway and advise the driver whether it is safe to pass the car ahead; a route guidance system may select for the driver the most efficient of alternate urban routes between two points at a given time.

An analysis of the facts at hand--scope of current research programs, documented needs, and future trends--clearly shows no shortage of subjects for highway research. Selecting those subjects to be included in a research program requires objective analyses of benefits, costs, urgency, available funding, and manpower requirements. The Department's Bureau of Physical Research has demonstrated that it has the ability to make such analyses.

Mass Transportation

Engineering personnel within mass transit operating agencies have been active for many years in solving "new problems." In general, however, this work has not been formalized to the degree that it can be considered a research program. The railroads, individually, have advanced experimental programs and have jointly supported research by the Association of American Railroads. Industry has conducted research on vehicles, power plants, and controls, but generally, this work has been in response to specific new requirements of corporate operating units, limited to the study of individual components rather than whole systems.

Recently, there has been a resurgence of interest in the engineering aspects of mass transportation. This has been partly due to the Federal Government's activities through the Department of Transportation and the Department of Housing and Urban Development. These agencies have made funding available for both "capital improvements" and "demonstration grants." The capital program has stimulated experimental work by industry to update on-the-shelf equipment items. The demonstration programs

have aroused public interest in transportation innovations, and to some degree, exposed the variety of detailed engineering problems that must be faced before major breakthroughs can be realized. Recently, an expert panel has analyzed research needs in high-speed ground transportation and made recommendations to the Federal Department of Transportation. Typical of their suggestions are the following:

> Contact vs. Fluid Support. Wheeled supports in rail contact have proved adequate at normal speeds. For high speeds, data are needed regarding contact dynamics, adhesion and wear phenomena, and performance limits during acceleration, deceleration, and constant velocity. Basic mechanics of fluid supports are well developed; however, applied experimentation is required concerning clearance tolerances, power requirements, and performance characteristics.
>
> Contact Rails and Collectors. For high-speed operations, difficulties have been experienced in transferring electrical current through shoes or collectors from rails to propulsion systems. Test programs are required to define the limitations of current equipment and disclose future needs.
>
> Braking. A sequential process might be used--aerodynamic braking with drag-producing devices at very high speed, then dynamic or regenerative braking, and finally, friction braking at low speeds.
>
> Guideway Materials and Construction. Conventional structural materials such as steel and concrete must be examined to ascertain whether they can withstand repetitive heavy loading, maintain close tolerances needed for stable and accurate alignment, and resist degradation under severe exposure.

In addition to enumerating other areas in which research is required, the panel emphasized the need to consider the whole system as a dynamic entity--passenger reactions, vehicle stability, suspension and support arrangements, roadbeds, and guideways. By evaluating component actions and interactions, individually and collectively, design criteria can be established that maximize passenger comfort and operational performance.

An overview of current experimentation and recent developments in the mass transportation field is provided in Appendix B; projects are characterized under the

headings: land-associated vehicles, water-associated vehicles, airborne vehicles, terminals, and equipment and facilities.

Evidence is overwhelming that there is no shortage of subjects for mass transportation research. Further major advances in these travel modes probably depend upon the solution of "hard" engineering problems. There have been a sizable number of demonstration projects concerning general feasibility or applicability: attention must now focus on the less dramatic "meat-and-potato" type of experimentation, from which true dividends will be received. The Department should provide direction and leadership in selecting subjects for a Statewide research program; assistance and recommendations should be obtained from engineering staffs of the mass transportation operating units.

FUNDING ENGINEERING RESEARCH

Industry continues to have considerable difficulty in determining appropriate levels for funding research. Those companies in the high technology category (drugs, electronics, etc.) may budget 10 percent or more of their gross earnings to research; those less sensitive to changing technology seldom budget less than 1 percent. All industry, however, is aware of the fact that engineering research is an economic necessity for efficient, effective business operations; industry recognizes the dangers inherent in under-budgeting this activity.

Public agencies responsible for the nation's transportation systems have the same "good business" responsibility as industry. They must realistically face the research funding problem, conscious of the need to optimize the value of their products and services; they must accept, as industry has, the fact that under-funding may be a more costly mistake than over-funding.

Highway Program

The engineering research program for highways proposed by the Department for Fiscal Year 1968-69 was $1.9 million (similar to 1967-68). This level of funding represents 0.4 percent of the Department's 1966 programs for highway construction and maintenance ($450 and $40 millions, respectively). Evaluation of the worth of the contributions made by the Department's on-going research program fully justifies this rate of funding; construction savings and service improvements made possible by past research effort have a definable value far exceeding research program expenditures.

Preliminary projections of highway research needs for Fiscal Year 1969-70, based on a construction program of $600 million and a maintenance program of $50 million, suggest a funding level of $2.6 million.

Federal Highway monies are used to partially finance the on-going research program; the current ratio of funding is approximately 30-percent State and 70-percent Federal, and it is anticipated that this ratio will continue. Funds from other Federal sources may be available in the future.

Mass Transportation Program

The Department will administer a State Aid Program for Capital Improvements to mass transit and airports, made possible by the transportation bond issue. While this program differs in character from the highway program, responsibilities with regard to the need for engineering research are similar. There must be assurance that investments provide facilities and equipment that are truly modern when viewed in the light of current technology, that there is minimum gamble of early obsolescence, and that there is maximum improvement of service.

As is the case at the outset of most new programs, it is not possible now to present a detailed plan for the Department's engineering research activities in mass transportation. Problem areas must be surveyed, specific subjects defined, experimental costs and benefits estimated, project priorities determined, and funding sources explored. It is possible, however, to estimate a funding level appropriate for initiation of this research activity and to identify requirements for those staff functions noted as Technical Management.

An analysis of the current status of technology clearly indicates an unlimited number of pertinent engineering problems requiring research effort for their solution ——the abundance of research subjects offers no restriction to the size of the program.

The Department's on-going highway research program is quantified by relating research expenditures to those for capital improvement plus maintenance - $1.9 million versus $490 million. The value of this 0.4-percent rate for highways has been proved; this rate appears appropriate for first-instance estimating of justifiable expenditures for mass transportation research.

The bond issue permits capital improvements over a 5-year period of nearly $2 billion (averaging $400 million annually). Applying a research funding rate of 0.4-percent, the Department's engineering research effort for mass transportation during the 5-year period should be at an annual level of $1.6 million.

For the post-bond issue period, analysis of available data suggests that the continuing requirements for capital improvements and engineering-oriented maintenance in mass transportation will be not less than $400 million annually —— a conservative projection for engineering research may also be $1.6 million.

FUNDING LEVELS FOR ENGINEERING RESEARCH

(thousands)

	Highways			Mass Transportation		
	1968 - 1969			5-Year Bond Period (Projected Annually)		
	Total	State	Other	Total	State	Other
Technical Management	230	70	160	177	177	None
Research Project	1670	500	1170	1423	570	853
Totals	1900	570	1330	1600	747	853
	1969 - 1970 (Projected)			Post-Bond Period		
Technical Management	272	82	190	177	177	None
Research Projects	2328	700	1628	1423	To Be Determined	
Totals	2600	782	1818	1600	To Be Determined	

The total research program can be divided into expenditures for Technical Management and Research Projects (previously described). With reference to the Department's highway research program, of the $1,176,000 budgeted for in-house staff salaries in 1968-69, it is estimated that $195,000 reflects Technical Management activities; support expenses for this effort are estimated at $35,000.

An appraisal of the scope and extent of Technical Management activities required for mass transportation suggests a funding level of $150,000 for staff salaries (1 Principal Engineer, 4 Associate Engineers, 4 Senior Engineers, and 6 Stenographic, Clerical and Technician positions) and $30,000 for support expenses. Considering the size of total programs, these amounts are in line with those applied to current highway research.

The Department's responsibilities for Technical Management activities will continue into the post-bond issue period. The projected funding level is the same as just noted: $177,000 ($150,000 staff salaries and $30,000 expenses).

Funding support for mass transportation research is currently being provided by manufacturers, local transit operating companies, private foundations, and Departments of Federal Government (Housing and Urban Development, and Transportation). The amount of support varies among agencies and within each agency by type of project. The Department's program should take advantage of all funding assistance available for the progression of Research Projects. For the purpose this report, it is assumed that 40 percent of project funding will be from the State and 60 percent from other sources.

Inasmuch as the Technical Management activities of the research program concern the Department's broad responsibilities for Statewide Transportation Systems as well as the Capital Improvement Program, and since this is a continuing activity independent of expenditures for Research Projects, it is recommended that it be funded by 100-percent State monies.

A RECOMMENDED ENGINEERING RESEARCH PROGRAM

The Department's three major responsibilities--the State Highway System, the Statewide Transportation System, and the Capital Improvements for mass transit and airports--individually and collectively require the support of a dynamic and aggressive engineering research program. This program must concern all modes of transportation and must produce data permitting management and engineering operations to determine worth and applicability of new technologies and innovations, to optimize the value of products and services, and to avoid the disaster of early obsolescence of capital equipment and facilities.

Three elements are essential to the research program: 1) an in-house research staff with capability to search out and identify subjects needing experimentation, and to examine, analyze, and disseminate research findings (Technical Management), 2) an inter-agency group to facilitate the exchange of ideas and information between the research staff and those responsible for operations, and 3) funding for the advancement of experimental work (Research Projects).

To meet the Department's responsibilities in engineering research, the following actions are recommended:

1. To recognize the broadened scope of the research program, and to assure efficient management, change the name of the Department's research unit from Physical Research to Engineering Research and Development, and assign this unit responsibility for Department-wide activities concerning engineering research.

2. To assure continued effectiveness of the Department's on-going highway research, approve the $1.9 million program defined in the 1968-69 budget submission and the additional engineering positions requested.

3. To provide research capability in mass transportation, establish a Mass Transportation Section within Engineering Research and Development, and approve a staff required for Technical Management activities--1 Principal Engineer, 4 Associate Engineers, 4 Senior Engineers, and 6 Stenographer, Clerk and Technician positions. Funding of this activity will require $177,000 of State monies.

4. To provide required communications between the research staff and those most knowledgeable of operational problems, appoint an Engineering Research Council for Mass Transportation to serve as a technical advisory group to the Commissioner. Council membership should consist of the Chief of Engineering from each of the metropolitan public agencies concerned with mass transportation. The Council, through use of task forces and consultants, would be expected to solicit assistance from industry, universities, and the private professional sector.

5. To recognize the need for experimental work in mass transportation, funding should be approved for the advancement of Research Projects. An expenditure level of approximately $1.4 million per year is estimated as appropriate for the 5-year bond issue period, of which 60 percent may be available from other than State monies. For 1968-69, State monies in the amount of $570,000 should be approved for Research Projects--maximum effort will be made to obtain matching monies from other sources.

Affirmative action on these recommendations will assure the continuation of an effective highway research program, and permit the initiation of research activities in the field of mass transportation.

The establishment of the Engineering Research Council for Mass Transportation will be first-order business in 1968-69. It is recognized that "committees" and "councils" are frequently ineffective and unproductive. However, in this instance, general agreement is believed to exist throughout the engineering profession concerning the need for coordination of efforts, as well as an enthusiasm for getting on with the job. Under Department leadership, this Research Council will be a "doer" group.

It is anticipated that there will be on-the-shelf research projects that are well defined and concern significant engineering problems. Such projects would be undertaken in 1968-69.

Technical manpower for the initiation of the mass transportation program will be obtained from the Bureau of Physical Research. Recruitment for new positions will be vigorously pursued. Ideas for improvements will be identified, defined, assembled into a statement of research needs, and priorities set. Sources of funding assistance will be explored and administrative procedures established. By 1969-70 major first-instance problems should be resolved and a detailed plan available for guidance of the continuing program.

Appendix A

HIGHWAY TRANSPORTATION/ A SURVEY OF CURRENT ENGINEERING RESEARCH

This Appendix indicates the range of engineering investigations now being pursued in connection with highway transportation. The discussion is in two parts:

- A brief presentation of the individual studies composing the current program of the New York State Department of Transportation's Bureau of Physical Research.

- An examination of general trends in the current work of other agencies.

For convenience of presentation, in each part the subjects have been grouped in four categories: 1) Design of Pavements and Structures, 2) Safety, 3) Materials and Construction Practices, and 4) Soil Mechanics and Foundations.

PROGRAM OF THE BUREAU OF PHYSICAL RESEARCH, NEW YORK STATE DEPARTMENT OF TRANSPORTATION

Current activities of the Bureau of Physical Research are restricted to the highway transportation system--more specifically, to the roadway subsystem as opposed to vehicle or operator subsystems. The Bureau is most active in what is generally termed "hard research," directed toward improvement of specifications, designs, and construction and maintenance practices. These activities encompass approximately 80 percent of the Bureau's effort in terms of dollars spent. Another 15 percent is devoted to evaluation of proprietary products, and about 5 percent to basic or fundamental research.

In the four subject categories discussed here, also in terms of dollars, design of pavements comprises 35 percent of the Bureau's total research effort, safety 25 percent, materials and construction practices 30 percent, and soil mechanics and foundations 10 percent.

Design of Pavements and Structures

Instrumentation and Testing of Concrete Bridges Reinforced with High-Strength Steel. Two experimental concrete bridges constructed with high-strength reinforcing steel have been instrumented and are being observed to determine long-time effects of weathering, creep, shrinkage, and traffic. Their performance is of national interest because use of high-strength deformed bars in concrete bridges is new to this country. Excellent performance and substantial savings are anticipated.

Field Tests of Horizontally Curved Steel Girder Bridges. Horizontally curved girders in bridges on curved alignments provide economic as well as aesthetic advantages. Work is in progress to investigate theoretical concepts used in curved girder design.

Castellated Beams. By increasing column spacing, buildings can be constructed with larger open areas, permitting more efficient use of floor space. Castellated beams can carry the heavier loads resulting from fewer columns. Current methods of designing these beams are being evaluated.

Analysis of Pipe Culverts. A recently completed study has provided the Department a rational method of estimating the service life of steel culverts. Current work is to provide similar information on aluminum culverts, and to define the causes of corrosion more clearly.

Temperature and Shrinkage Stresses in Concrete Bridge Piers. Concrete bridge piers are being studied to determine the magnitude of stress induced by temperature and shrinkage differentials between capbeam and footing. As evidence regarding the magnitude of these stresses is incorporated into design, more realistic criteria will be established and substantial economies achieved.

Measurement of Portland Cement Concrete Pavement Thickness by the Ultrasonic Method. This study is to demonstrate the practicality of commercially available ultrasonic devices in non-destructive measurements of pavement thickness. If successful, this method may supplement or replace conventional extraction of cores for thickness measurements, which is both expensive and inefficient.

Rehabilitation of Old Bituminous Surfaces. Surface dressings currently used by various agencies to rehabilitate bituminous pavements are being studied. Economical and effective methods are urgently needed for periodic rejuvenation of older pavements.

Bituminous Resurfacings. Bituminous resurfacings on rigid pavement are being evaluated in several test installations, to provide a basis for improved resurfacing design criteria. A study is underway to determine the serviceable life of a bituminous overlay on a flexible pavement, and to establish criteria to aid the maintenance engineer in deciding which of the Department's two current retread thicknesses should be chosen in a given design situation.

Analysis of Existing Flexible Pavements. Performance of flexible pavements varying in cross-sectional design is being evaluated throughout the State over a 3-year period, through measurements of deflection and calculations of Present Serviceability Index.

Flexible Pavement Base Course Study. Performance of various base course materials for flexible pavements is being studied in test sections built into State highways. The results will provide performance equivalency factors for these materials.

Analysis of Existing Pavements. Corrosion-resistant load transfer devices in transverse joints have been under field evaluation for 7 years. Several joints will be cut from pavements to determine the condition of these devices.

Experimental Concrete Pavements. Construction has been completed on an experimental pavement utilizing various cross-sectional designs and base course treatments. This study's results will provide more economical rigid pavement designs.

Construction Control of Rigid Pavement Roughness This investigation will determine the causes of roughness in new concrete pavement by correlating construction practices with roughness measurements taken with a California Profilograph.

Safety

Performance of New Highway Barriers. The new standard barriers introduced in 1965 have been tested under controlled conditions and found to be satisfactory. Accident statistics are being collected on barrier collisions to compare actual field perfor-

mance of old and new barriers and to verify the expected reduction in severity of accidents involving the new designs.

Warrants for Highway Barriers. Considering initial cost and the fact that even the best barrier is a potential hazard to occupants of a vehicle leaving the road, it is important to place barriers where they are needed. Development of new warrants will insure best use of the new barriers and safer driving for the public.

Evaluation and Testing of Highway Barriers. Highway guide rails, median barriers, gore protection devices, and other roadside safety accessories are being evaluated under various impact conditions. This program will include development of additional accessories and other roadside improvements.

Roadside Features Related to Safety. This study consists of identifying and describing roadside hazards, and determining respective frequencies and severities of collisions with each type.

Audible Roadway Delineators. This project will evaluate the design, cost, and effectiveness of audible delineators and cross-pavement rumble strips used to warn the sleepy or inattentive driver that he is wandering from the road, or to alert him to a required change in speed or direction.

Development of Skid-Resistant Bituminous Surfaces. Current work includes use of a towed skid trailer to evaluate specially designed skid-resistant surfaces to determine the most economical ways to provide skid-resistant pavements for each locality in the State.

Skid Resistance Level of the State Highway System. Work is underway to determine present levels of skid resistance throughout the State highway system. From these data, major problem areas will be located as well as isolated slippery sections of otherwise suitable pavements.

Glare Screens. Glare from oncoming vehicles can create considerable driver discomfort and potentially hazardous situations. A study is underway to select and evaluate several types of glare screens for use under various road conditions.

Roadway Marking and Delineating Materials. To aid the driver, various markings and road delineators are used. Current research is directed toward improving pavement striping materials, guide rail paints and reflectors, and shoulder delineators (paints, marble chips, etc.).

Field Evaluation of Rail Lighting. A unique type of lighting, installed in bridge rails, has been developed for Albany's South Mall Interchange. The system will be evaluated when the interchange is open to traffic.

Materials and Construction Practices

Pore Characteristics of Coarse Aggregates. Information is being gathered about the pore systems of rocks used as concrete coarse aggregate, and correlated with the aggregate's resistance to freeze-thaw damage when placed in concrete.

Density Studies of Asphalt Concrete. This study will determine what influence such factors as compactive effort, mix temperature, foundation support, and traffic have on asphalt concrete density. A general relationship has been established for top course mixes. Additional study will provide similar data on binder and base course mixes.

Additives and Admixtures for Asphalt Concrete. This long-term study is concerned with determining the influence of various additives or admixtures on asphalt concrete pavement performance.

Crushed Gravel Coarse Aggregate in Asphalt Concrete. The possibility of using crushed gravel coarse aggregate in asphalt concrete pavements is being investigated. Economies might be realized if localities having abundant gravel resources were able to utilize them for this purpose.

Hardened Portland Cement Pastes of Low Porosity. The purpose of this research is to develop concrete, by the use of low porosity cement pastes, having greater strength and volume stability than are now possible.

Uniformity Studies of Portland Cement Concrete. This study will develop information necessary to institute a concrete quality assurance program based on statistical principles. The study is proceeding with extensive sampling and testing. Uniformity of fresh concrete is being measured in terms of slump, air content, unit weight, and other properties.

Accelerated Strength Tests of Portland Cement Concrete. Various methods of predicting 28-day and other strengths of concrete at early ages will be evaluated, including the application of ultrasonics and several rapid curing procedures.

Evaluation of Viscosity Grading of Asphalt Cements. This study's purpose is to determine what influence a change from penetration grading of asphalt cements to viscosity grading will have on asphalt concrete mixing, pavement construction, and in-service performance.

Asphalt Concrete Uniformity Simulation. This project is to develop a capability of simulating production quality control tests by computer. Results of tests performed on current asphalt concrete production samples will be entered into the computer to form a master data blank, providing a statistically sound basis for quality control in all plants.

Protective Coatings for Steel Structures. Considering the complexity and cost of periodic repainting of steel structures, long-time coating durability is desirable. Initial work under this project is a liter-

ature search to identify coatings that might reduce repainting. The more promising coatings will then be field-evaluated.

Constructing and Sealing Concrete Pavement Joints. Although much has been learned in the past few years, several problems of joint construction and sealing remain unsolved. The most promising methods developed in previous studies will be incorporated into a single new test installation. Concurrently, new laboratory testing procedures will be evaluated to improve the correlation between field performance and laboratory results.

Repair and Protection of Concrete Structures and Pavements. Effective, economical methods are being sought for restoration of damaged concrete surfaces. Included are non-destructive testing for extent of distressed area, methods of preparing surfaces for patch application, and various coating/patching materials.

Soil Mechanics and Foundations

Analysis of Recharge Basins. Rational criteria and procedures are being developed for design, construction, and maintenance of recharge basins, used extensively on Long Island. Appropriate theory will be formulated to explain the movement of water through partially saturated soils, and the performance of a prototype basin will be observed to establish the rate and cause of diminished infiltration with time due to solids and other clogging of the permeable strata. ata.

Engineering Soil Survey of Various New York Counties. In this continuing project, the Department's Bureau of Soil Mechanics is preparing engineering soil survey reports for the State's individual counties. This involves testing soil samples, compiling and analyzing laboratory test data, appraising the engineering significance of various soil types with the aid of aerial photographic interpretation, and preparing an engineering report to complement each County soil survey published by the Soil Conservation Service.

Rapid Embankment Construction Control Test. Previous research indicates that present density-oriented methods of compaction control are extremely conservative when compared to conditions actually required for adequate performance. This research will establish a rational basis for isolating the dynamic properties required for adequate performance of compacted embankment soils, and develop field measurement methods permitting rapid, accurate assessment of compaction acceptability.

PROGRAMS OF OTHER AGENCIES

Engineering research in highway transportation has been actively pursued for many years by producers and consumers, by public agencies and private, and by academic institutions as well as those charged with operational responsibility. The volume of this activity in the United States alone is believed to exceed $35 million annually. Approximately 2,000 agencies in this country are now involved in 4,000 different research and development projects. Yet, these efforts consume less than one-half of one percent of total expenditures for highway transportation.

Highway engineering research--in the traditional category of "hard research" concerned with the physical plant--is being conducted simultaneously at several levels: theoretical, applied, developmental, and prototype evaluation. Research in progress by other agencies is broadly discussed here in the same four classifications just used in describing the program of the Bureau of Physical Research: 1) Design of Pavements and Structures, 2) Safety, 3) Materials and Construction Practices, and 4) Soil Mechanics and Foundations.

Design of Pavements and Structures

Present methods for designing pavements are semi-rational in that no clear relationship exists between properties of the pavement components, stress levels imposed by loadings, and capacity of the pavement system to function acceptably for a given period. Reliable, rational structural design methods would permit planning and design of pavements having predictable performance under specified traffic and environment, as well as providing sound evaluation procedures for new paving materials and alternate designs. A substantial segment of the overall highway research effort is being channeled into these areas:

- Studies of the flow and fracture behavior of paving materials and mixes under cyclic and dynamic loads, including stabilized and natural soils.
- Analysis of stress distribution in layered systems.
- Studies of pavement-vehicle interactions.
- Tests of model and prototype pavement systems.
- Studies of structural defects in pavement systems and their causes, such as blowups, cracking, joint seal failure, improper load transfer, pumping, etc.

In addition to this work oriented toward roadway pavements, many new design concepts and materials are being evaluated for highway bridges and incorporated into them. These include high-strength steels, composite construction, prestressing, box and curved girder configurations, and wide use of precast units.

New criteria for bridge design, such as ultimate load concepts, are also coming into use. These factors are raising serious questions concerning the adequacy or justification for some current design requirements. Much attention is being given to developing methods of predicting the dynamic response to live loads of various elements of highway bridges.

Finally, considerable effort is being expended to establish rational performance criteria and related theories for predicting performance of pavements and bridges, particularly with regard to application of loads and the influence of climate. This problem involves relating structural elements with known properties to predetermined minimum acceptable levels of performance, and includes:

- Simulating or identifying both static and dynamic loads during anticipated life.

- Predicting climate and other environmental factors.

- Determining the response of structural elements to load and environment.

- Defining mechanisms of failure (such as fatigue, corrosion, creep, volume change, abrasion, etc.).

- Developing devices to measure present condition.

The performance prediction problem relates not only to structural adequacy, but also to maintenance of such pavement and bridge deck surface characteristics as smoothness and skid resistance. Without such criteria, it is impossible accurately to predict future maintenance and replacement needs, thereby taking advantage of the efficiencies possible through cost effectiveness techniques.

Safety

Major research efforts are being directed toward enhancing safe, efficient movement of people and goods over the highway and street network. These programs are producing new traffic aid systems that will reduce urban congestion, improve the safety of traffic flow, increase the certainty of reaching a destination on schedule, and aid the vehicle operator in executing the various maneuvers required by modern driving. Some of the research and development currently underway in this area includes the following subjects:

- Protective structural systems to reduce severity of off-road, fixed-object accidents including barriers and guide rails as well as frangible, breakaway, and energy absorbing devices supporting lights, signs, etc.

- Glare reducing systems to radically improve nighttime roadway delineation and guidance.

- Improved performance under adverse environmental conditions, through better understanding of

the interaction between the tire and pavement surface in relation to traction and braking.

- Traffic control for prevention and minimization of accidents, particularly rear-end and head-on collisions on rural two-lane highways, single vehicle accidents in rural areas, urban intersection accidents, and accidents resulting from inadequate night visibility.

- Optimization of urban traffic flow through more advanced systems to maximize street and intersection capacity, design signal systems, and develop information devices to route traffic through the street network. A computerized system is envisioned for traffic control activation, capable of traffic surveillance and evaluation of flow resulting from specific control actions.

- Traffic merging and control systems to increase capacity and reduce hazards at high-volume freeway interchanges.

- Analysis of the mechanics of interurban traffic stream flow to determine optimum methods for improvement of efficiency of movement.

- Study of the functions of transportation by developing comprehensive analytic models of transportation performance requirements and constraints, in order to evaluate alternative systems.

Materials and Construction Practices

Comparison and evaluation of the relative quality of highway materials have been and continue to be troublesome problems. Major research efforts are underway to develop rational testing procedures in the following areas:

- Basic composition and structure of materials and their relation to engineering properties (example: characterization of the pre-water system in aggregates).

- Fundamental interactions within materials systems (example: asphalt-aggregate bond).

- Environmental effects on materials systems (example: mechanisms of failure of conventional traffic paints).

- Reactions and mechanisms of special treatments for improving properties of materials systems (example: water-reducing and set retarding and accelerating admixtures for portland cement concrete).

Highway construction involves enormous quantities of natural and other bulk material. For several years, efforts have been underway to bring them and the construction operations by which they are incorporated into the highway system under modern statistical concepts of quality control and acceptance

sampling and testing. Much of this research has taken the form of measuring uniformity, as a basis for devising specifications and appropriate control and acceptance procedures.

Finally, efficient utilization and benefication of natural aggregate is a subject of continued study.

Soil Mechanics and Foundations

Activity in the general area of soil mechanics and highway soils includes:

- Methods of evaluating soil performance in construction (example: how to prevent settlement or expansion of soils adjacent to structures).

- New techniques and materials for stabilizing and conditioning soils (example: cementers (portland cement and lime), conditioners (chlorides), and waterproofers (bitumen)).

- Theories and methods for analyzing soil masses and soil structure interactions (example: stresses and displacements in high fills and embankments).

- Validation of soil mechanics theories by model and prototype measurements (example: measurement of skin friction of piles).

- Development of area relationships of material properties (example: use of infrared and color in airphoto interpretation).

- Definition and measurement of critical properties and relationships governing soil and rock behavior (example: load-supporting capacity of roadway base course materials).

- Detrimental effects of environmental factors, including frost and moisture, on soil and rock behavior (example: the accumulation of moisture beneath pavements and its effects).

Appendix B

MASS TRANSPORTATION/A SURVEY OF CURRENT ENGINEERING RESEARCH

This Appendix provides a rapid survey of innovations in mass transportation technology, either undergoing current study or proposed for the future. The emphasis is on categories and types of vehicles; although engineers have devised many other systems of classification, the discussion here deals in succession with land-associated vehicles, water-associated vehicles, airborne vehicles, terminals, and miscellaneous equipment items and other facilities.

The Metroliner

This electric-powered passenger train, a demonstration project sponsored by the Federal Government's Office of High-Speed Ground Transportation, is scheduled to begin trial service early in 1968 on the 225-mile New York-to-Washington leg of the Northeast Corridor. Estimated to cost a total of $56 million, of which $11 million represents Government funds and the balance is invested by the Penn Central Railroad, the 2-year demonstration will feature a fleet of 50 specially designed multiple-unit (self-propelled) cars. Government performance specifications contain many precedent-breaking requirements, including a maximum speed of 160 mph, accelerating to 125 mph in 2 minutes and to 150 mph in 3 minutes, fast service and emergency braking, and advanced standards of riding comfort at all speeds.

Results of this corridor project will answer many vital questions, including: whether people will return to the rails for medium-haul trips if they are provided fast service of quality comparable to that available from the airlines, whether high-speed track and roadbeds can be constructed and maintained economically, and whether passenger trains can be operated profitably. Preliminary results on a 21-mile test section suggest that existing track upgraded for high speed may be maintained economically without need for more permanent types of roadbed.

The TurboTrain

Complementing the Metroliners in the Northeast Corridor demonstration program, and also sponsored by the Office of High-Speed Ground Transportation through a $2.1 million contract, are gas-turbine powered trains scheduled to run the 230 miles between New York and Boston over New Haven Railroad tracks. Aerodynamically designed by the United Aircraft Corporation System Center under performance specifications similar to those for the high-speed electric trains, two or three-car aluminum TurboTrains will be leased by the Government and operated by the NHRR during a 2-year period beginning January 1968. Each test train will have a powered passenger car at each end, one pulling and the other pushing the passenger coach between.

TurboTrains will also be placed in regular service on the Canadian National Railways between Montreal and Toronto. Two 14-car sets, each with a total capacity of 660 passengers, will make the 335-mile run between Canada's two largest cities in 4 hours, an average of 84 mph.

The Tokaido Express

Within 2 years after initiating service in October 1964, the 320-mile, $1-billion-plus high-speed electric train between Tokyo and Osaka proved so successful that planning started on extensions of 400 miles to Hakata at the southern end of Japan, and 330 miles to Morioka in the north. The Tokaido's popularity

HIGH-SPEED GROUND CONTACT TRACKED GUIDANCE
Land-Associated Vehicles

Japan's Tokaido Line

The Metroliner

The TurboTrain

is evidenced by the fact that during the first 2 years of operation, 62 million passengers were carried a total of 19 million train miles. The passenger record on a single day was 200,000.

The train's success is attributed to its providing all features demanded by the typical traveler: speed, comfort, frequent schedules, and moderate rates. Speed on the double-track, standard-gage electric railway is assured in a number of ways: there are no grade crossings of any kind; all curved sections of track have a radius of 8,200 ft or more and are easily negotiated at top speed; travelers have a choice of a super-express making only two intermediate stops, or a limited express stopping at 10 stations; normal operation speed is 125 mph; traffic is limited to express passenger and freight service; and train control and signaling are automatically monitored from a master panel in Tokyo. The 50 twelve-car trains in the system make a total of 60 roundtrips daily.

In place of a locomotive to provide propulsion, all cars are arranged as permanently coupled multiple-unit sets, each car having all powered axles. Dynamic brakes decelerate the train to 45 to 50 mph, where normal air brakes take over. Two interesting features are an override safety device permitting the on-train operator to de-energize both tracks at both ends of the train for 35 miles, and louvers along the top of each car adjusted electronically to eliminate air-pressure discomfort when entering and leaving tunnels. All rail is welded in 4800-ft lengths, and supported by prestressed concrete ties, except at switches and steel bridges. Anemometers installed at 30 key points along the line send an alarm signal to the Tokyo control center if wind velocity exceeds 45 mph. In addition, seismographs installed at substations automatically disconnect power in an area affected by an earthquake of a certain intensity.

Fort Worth Modified Street Cars

In 1963, Leonard's Department store in downtown Ft. Worth, Texas, successfully stemmed the outflow of customers to suburban shopping centers by providing free rail transit service from an outlying parking area directly into a station in the store's basement. The system has been so enthusiastically accepted by shoppers and downtown workers (purchases are not required to use the service) that the owners have had to enlarge the parking lot to accommodate over 5,000 automobiles, and add more track and two more stations within the enlarged lot. Store officials estimate daily traffic to range from 10,000 to 15,000 persons during busy shopping seasons, with peaks of over 70,000 on some days. Equally important, downtown traffic congestion has been dramatically reduced. This success is partially attributed to the fact that the rail service is available six days a week, beginning at 7:30 a.m., even though the store does not open until 9:00 a.m.

Service is provided by five independently driven modified PCC (President's Conference Commission) electric street cars originally built for Washington, D.C. Operating on a 3/4-mile, completely grade-separated rail line, the cars are 44-ft long and each has a capacity of 100 persons. Original equipment and features include magnetic disc brakes, electric heating, a smooth, quiet ride, and rapid acceleration/deceleration. The new owners added air-conditioning and a new metal exterior shell to each car. The trip from the parking lot to the store takes about 3 to 9 minutes at the normal operating speed of 30 mph, but the cars are capable of 60 mph.

Cleveland Airport Trains

Cleveland, Ohio, is the nation's first city to coordinate air travel with in-town mass rail transit. When completed late in 1968, a 4-mile extension of the existing 15-mile rapid transit system will speed air travelers comfortably and inexpensively between Hopkins Airport and the underground railroad/suburban commuter terminal in the heart of Cleveland. Travel between the airport and downtown, which usually takes about 40 minutes and as long as 1 hr during peak traffic, will be cut to 20 minutes. This will be accomplished by 20 new stainless-steel, 80-passenger electric cars capable of traveling 60 mph. Conventional in style, the trains employ new concepts in braking, coupling, and safety mechanisms, and will offer riders air-conditioned comfort, luggage racks, greater-than-standard seat spacing, and improved lighting. The extension will also serve the city's thriving industrial complex along the route. HUD is participating in rolling stock purchase, now estimated as costing $4.5 million.

Canadian GO Transit

The Government of Ontario (GO) Transit, opened to service in May 1967, already is a successful venture in providing urban mass transportation in the Toronto metropolitan area. It is a new government-subsidized commuter railroad service along a 60-mile lakefront route of the Canadian National Railways. Providing 16 stations along the route, "Park-'N'-Ride" facilities, and convenient access to the Toronto subway, GO is intended to induce commuters to use mass transportation instead of automobiles, thus reducing street traffic congestion and the need for more highway construction. Equipment consists of 40 coaches, 9 self-propelled units, and 8 locomotives. All cars are air-conditioned and have translucent ceilings that "shower" light from concealed fluorescent installations.

The Ontario Government assumed all capital costs for the service. Total investment amounted to $15 million and covered new equipment, stations, changes to trackage, and signaling. The Government also will assume annual operating deficits estimated at about $2 million. By comparison, cost of constructing a six-lane expressway ranges between $3.5 and $4 million a mile. Government officials also note that the cost of an elevated highway is about $16 million for a single mile, or about the same as the entire 60 miles of GO-Transit.

BART (Bay Area Rapid Transit)

San Francisco, one of the first major U.S. cities to acknowledge the importance of adequate public transportation, is constructing a rapid transit system to serve the growing Bay area. When completed, it will connect all cities and communities in the region by a 75-mile network of tracks along gracefully curved aerial lines, new subways, and tunnels. Among the system's unique features, its entire fleet of 450 streamlined cars will be completely controlled at speeds up to 80 mph by a $30 million computerized automatic train control system. Fare collection also will be automated. Car interiors will be luxurious, providing carpeting, airline seats, glare-free lighting and large picture windows, and will have no advertising car-cards. Made possible chiefly by a $729 million bond issue approved by voters in 1962, cost is currently estimated at more than $1 billion.

Several new design and operating concepts incorporated in the system are being tested under demonstration grants from HUD. A 4-1/2-mile "Diablo" track has been built to test full-scale models of BART's transit car, as well as new propulsion and braking components. Also, under a HUD Urban Beautification Demonstration Grant, a continuous linear park designed for general public use is being created under a 2.7-mile section of BART's curved aerial track.

The Turboliner

In September 1966, New York's Metropolitan Commuter Transportation Authority started test runs of the world's first gas turbine-electric rail commuter car, on the Long Island Railroad. A second phase of the experiment--launched late in 1967--combines use of the gas turbine car with the existing Long Island electrification system. In non-electrified areas the car is driven by gas turbines coupled to high-speed alternators. Upon entering an electrified zone the car automatically switches to third-rail power.

In terms of railroad operation, the new turbine engine may reduce the frequency of major overhauls, cut down delays caused by breakdowns, and reduce track maintenance requirements because of the new car's lighter weight. The first phase of the test program will cost $1.4 million, two-thirds of which is financed by a grant from the U.S. Department of Housing and Urban Development and one-third by the State of New York and the Budd Company, builders of the new car. MCTA and the Tri-State Transportation Commission are co-administrators of the project.

PATH Trans-Hudson Transit

Modernization of the bankrupt Hudson & Manhattan Railroad commenced in 1962 with creation of the Port Authority Trans-Hudson (PATH) Corp. It has designed and purchased a fleet of 90 modern rapid transit cars for the nation's first fully air-conditioned service.

COMMUTER GROUND CONTACT TRACKED GUIDANCE
Land-Associated Vehicles

BART prototype car

Trans-Hudson (PATH) cars: past and present

LIRR-MCTA Turboliner car

Other items in the program include constructing a new Hudson terminal in lower Manhattan's World Trade Center and improving the station at Jersey City's new Journal Square transporttion center; renovating all other stations in New York and New Jersey; rebuilding the signal system for faster, more dependable service; replacing the electric traction power system to provide more efficient, reliable train power; rehabilitating track, tunnel drainage, and ventilation; and renovating maintenance shops and car yards.

Most recent figures indicate an annual PATH passenger load of 27 million, with a weekday average of 100,000. Peak hour service provides trains every 3 minutes. The first 5-years work required commitment of $70 million, but PATH has succeeded in reducing passenger fares.

The Aerotrain

The air-cushion vehicle has been developed extensively in recent years for use over both land and water. For land operation, lack of lateral stability dictates that such a vehicle be positively guided if high speeds are to be attained. The Aerotrain is an example of such a system. When fully developed, cars are intended to carry 80 passengers in relative silence at speeds up to 200 mph. A model has been constructed and is now being tested in France. Propulsion by jet engine both pushes the car and provides air for support. The track is concrete and is straddled by the car. The model has attained a speed of 233 mph.

The Sky Bus

The Allegheny County Port Authority (Pittsburgh, Pa.) has placed in service an electric-powered train guided over an elevated roadway. Described as "well-suited to medium-sized towns (too small for a conventional railway commuter line and too large to be efficiently served by buses)," it consists of lightweight vehicles operating singly or in pairs, resembling buses and running on four pairs of rubber tires. Service is around-the-clock with trains running every 2 minutes. The automated system is operated by a central computer. The project is being assisted financially by HUD, with the goal of developing a network having capital and operating costs below those of conventional transit.

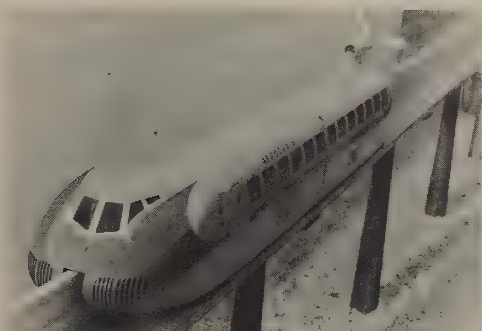
The Expo Express

Serving as primary means of on-grounds transportation at Montreal's 1967 World Exhibition, the Expo Express, operating on an elevated steel railroad track, was a resounding success. In the first three days of the fair, an estimated 1.4 million riders traveled the 3.7-mile train route from the fair's main entrance to the La Ronde amusement area (with three intermediate stations at main exhibit areas). Total patronage during the 6-month exposition is believed to have substantially exceeded the anticipated 30 million riders.

Principal contributor to train's success was the automatic train operation system. The single attendant

The Expo Express

ELEVATED/LEVITATED TRACKED GUIDANCE
Land-Associated Vehicles



The Aerotrain

The Sky Bus

on each train was responsible only for operating car doors, and for pushing a "GO" button when a train was ready to leave a station. All other functions, including starting, maintaining speed and distance from other trains, braking, and stopping at stations were automatic, with direction from and communication to a control center. Each train was equipped with an override control allowing the operator to take over and run the train in an emergency. Each of the 48 aluminum cars had three doors and large windows, seated 80 persons, and accommodated approximately 120 standees. Operated in eight units each consisting of an electrically powered cab car and five intermediate cars (steel wheeled), each train averaged 20 mph.

The Tube Train

Under "Project Tubeflight," a tube train is being developed at Rensselaer Polytechnic Institute. Essentially, this is a system in which aerodynamically supported and propelled vehicles travel at high speed (300 mph) in non-evacuated tubes. Thrust is generated by a continuous transfer of air in the tube from immediately in front of the vehicle to its rear. Use of bladeless fans as thrust generators is being considered. Safety in all weather requires an enclosed guideway for such a vehicle, and the tube is considered the most practical guideway form because of good structural characteristics. This enclosure constitutes a major portion of the cost. At present, experiments are being carried out on a model operating in a 1000-ft long, 12-in diam tube, set up along the Hudson River opposite Albany.

The tube train concept has many advantages in addition to its high speed. Operating in a tube at or below ground level, it eliminates such undesirable aspects of other transportation modes as noise, vibration, air pollution, and uncontrolled strip development or blighted areas along its line. Further, it presents no hazard to persons living or traveling adjacent to it.

Teletrans

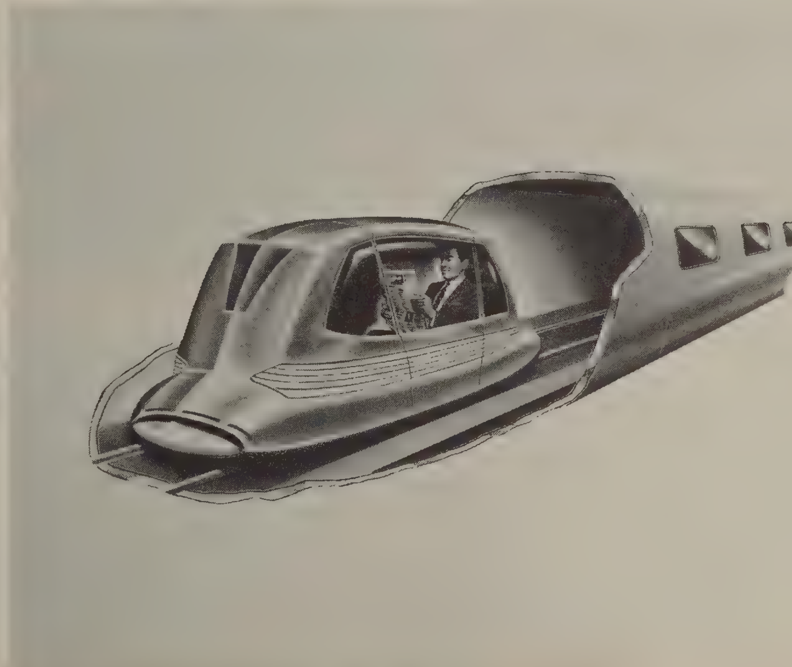
"Teletrans" is a system of single-passenger vehicles powered by an electro-magnetic drive. The vehicles run in tubes on rails and can be pre-routed by computer. So far the only practical applications have been for baggage shuttle systems at airports, where the vehicles are on tracks but not in tubes.

The Tube-Taxi

Small cars, electrically powered and operating in tubes suspended over existing streets have been suggested by a British engineer. Driverless vehicles would carry up to four passengers at speeds of 35 mph. The vehicles would run quietly on rubber tires in a guideway, and would be capable of going up and down reasonable grades. The cars would be automatically routed, and special-bodied vehicles could carry up to 800 lb of freight. The automatic guidance could be coupled to a computer so that empty cars would be returned to points of greatest need. The system is suggested as operating from stations about 1/2-mile apart in a central city and perhaps 2 miles apart in suburbs.

RPI's "Project Tubeflight"

TUBE GUIDANCE/Land-Associated Vehicles



Teletrans "Telecar"

Rail Buses

Buses that can operate on both roads and railway tracks have been demonstrated in two independent studies. The Port of New York Authority and the Metropolitan Commuter Transportation Authority are hopeful that their "Rail Bus" will facilitate mass transportation of passengers between mid-Manhattan and Kennedy International Airport. In Pennsylvania, the Philadelphia Suburban Transportation Co.'s "Hi-Rail Bus" would use highways in the suburbs, and enter congested city areas on rails.

Both demonstrations involve the same concept--a conventional rubber-tired bus outfitted with smaller steel wheels retracted beneath the baggage compartment during travel on highways. When riding on tracks, driving power is provided by the inner rail-riding tires of the dual rear rubber-tired wheels, while the front "highway" wheels are suspended above the rails. Cost of the hydraulic, eight-wheel conversion kit ranges from $10,000 to $15,000. Speeds up to 60 mph have been attained on dry rails. Wheel-slippage and loss of traction has been encountered, but appears to be a problem that can be overcome.

Mini-Buses

Some concern exists that urban bus service is not as effective as possible when large buses run relatively infrequently. To provide more service in downtown areas, the effectiveness of small buses running on closer schedules is being evaluated under a demonstration project sponsored by the U.S. Department of Housing and Urban Development. Frequent service at low fares may induce people to leave their automobiles at home and "hop-shop" by bus.

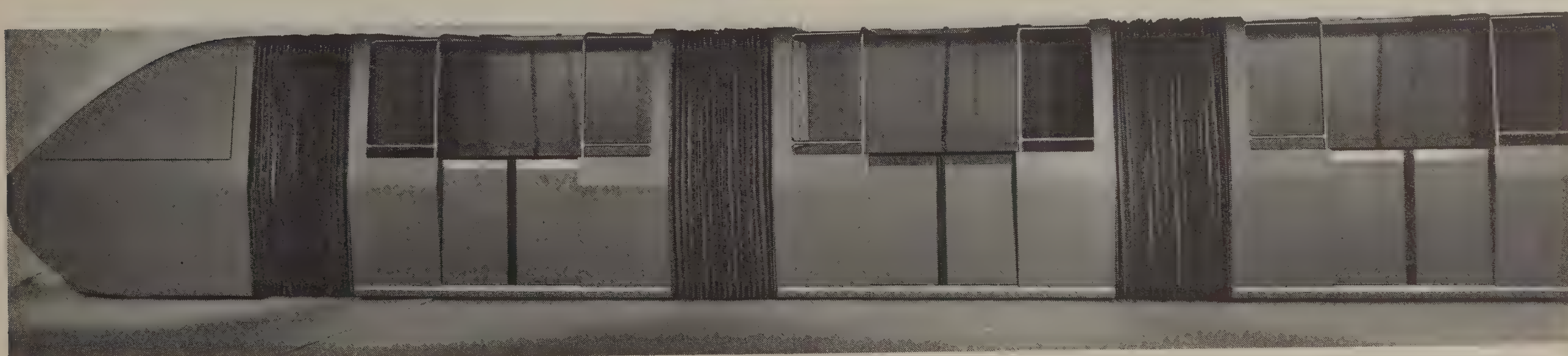
"Guide-O-Matic" Shuttle Trains

Apparently the first driverless, trackless passenger train, the "Guide-O-Matic" system of the Barrett Electronics Corp. was introduced late in 1967. Four such trains will be installed at the Houston International Airport to transport passengers and their hand baggage to and from the terminal, flight gates, ticket counters, and escalators to parking areas. Rubber-tired trains, driven with battery-powered electric motors, will be guided by a single wire enbedded in the floor. Trains will run about every 2 minutes and make programmed station stops. Zone blocking traffic control is also electronic, and each train has an optical scanner that will trigger an unscheduled stop if it "sees" another train ahead. The four trains are designed to handle more than 20 passengers a minute during peak periods, and more than 23,000 passengers a day. Plans call for expansion of the Houston installation to 12 trains operating over a 2-mile route, along with other refinements over the next 10 years.

(Left) PNYA-MCTA "Rail Bus"

(Below) HUD "Minibus"

DUAL GUIDANCE
FREE MOVEMENT
ELECTRONIC GUIDANCE
Land-Associated Vehicles



Barrett Electronics Corp. "Guide-O-Matic" Shuttle Train

The Auto-Train

In demonstration runs between Washington, D.C. and Jacksonville, Fla., a new long-haul rail service for autos and their passengers is to be tested for feasibility. Newly designed rail cars are to be boarded at two levels from ramped terminal platforms located on major suburban highway networks. The Auto-Train provides restaurants, lounges, entertainment areas, and snack bars in special service cars for convenience during the 750-mile trip. During the 18-month trial period, the Seaboard Coast Line will conduct the demonstration under a $4 million grant from the Office of High-Speed Ground Transportation for testing market potential, engineering studies, and procuring three locomotives.

The Starrcar

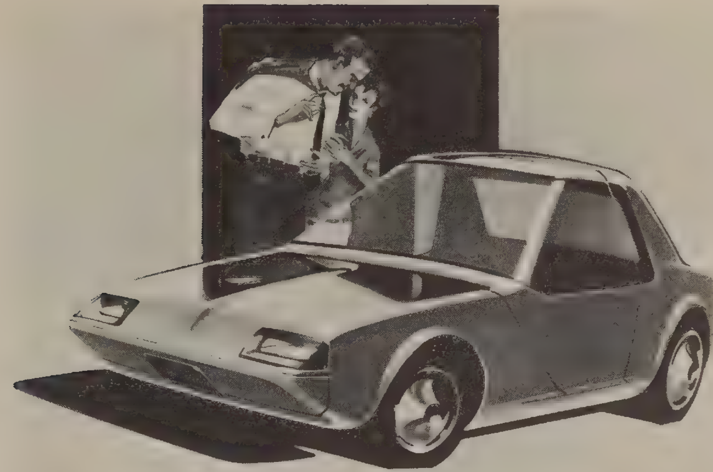
"Starrcar" is a three-passenger vehicle capable of running on steel rails or the road. Thus, it combines the convenience of portal-to-portal transportation with the speed of mass transit. The vehicles are battery-powered on the road and electric-rail-powered on the system. The manufacturer currently has a test system several hundred feet long at his plant.

Electric Mini-Autos

Internal combustion exhaust emission was proved a few years ago to be a major, health-hazardous contribution to Los Angeles area air pollution. Concern there prompted other cities to review the problem, and reach general agreement that large numbers of autos, buses, and trucks contribute significantly to air pollution. Examination of auto commuter traffic indicates most vehicles carry only the driver or seldom more than one additional passenger. These facts, plus the chronic inadequacy of urban parking space, explain recent interest in low-exhaust-emission mini-autos.

This concept of personalized mass transportation has been studied in depth by the Cornell Aeronautical Laboratories, which uses the term "Urbomobile" to describe this class of vehicle. Several agencies have designed battery-powered mini-autos and some have built prototypes. For example, the University of Pennsylvania, under contract with the U.S. Department of Housing and Urban Development, has designed a small limited-emission car for commuters. This particular car has a small gasoline engine as well as battery power and can operate on either power source. It has a top speed of 60 mph, a range of 100 miles, and being only 9 ft long, three can be parked perpendicular to a curb in the space normally occupied by one car.

Four prototype electric mini-autos were demonstrated in London during the spring of 1966. In this country, Rowan Controller Co., Westminster, Md., has exhibited prototypes of an electric mini-auto they hope to market. General Electric also has a prototype as do Westinghouse, Ford, and American Motors.



PROTOTYPE ELECTRIC AUTOMOBILES

"Minicar" (HUD – University of Pennsylvania)

"Comuta" (Ford Motor Co.)

"Experimental Electric Vehicle" (General Electric)

The top speed and mileage ranges for the American-made cars have been reported as 44/108, 55/80, 25/50 and 55/150. Speed and range is limited by present capabilities of lead-acid storage batteries. Development of lighter, more efficient batteries may increase both speed and range. In the meantime, the Williams Engine Co. of Ambler, Pa., has produced a steam-powered car with performance characteristics comparable to present automobiles with internal combustion engines. The steam car emits only 1/5 to 1/60 as much air contaminants.

The NYS Safety Sedan

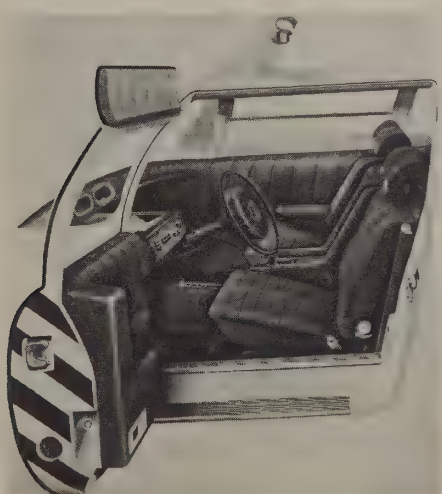
Building greater safety into conventional autos is of course a subject of great current public concern. The New York State Safety Sedan is a particularly appropriate example of the application of engineering talent to the solution of automotive safety problems.

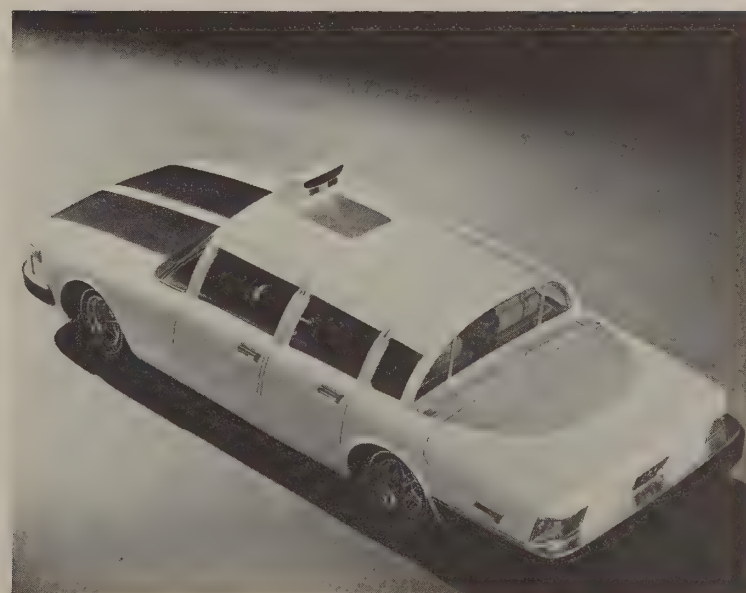
The Sedan was designed and a scale model built as a result of 1965 legislation introduced by the Joint Legislative Committee on Motor Vehicles and Traffic Safety, under chairmanship of State Senator Edward J. Speno. Developmental studies were performed by the Republic Aviation Division of Fairchild Hiller Corp., under administration of the New York State Department of Motor Vehicles.

The Sedan has a blunt front end and foam rubber bumper that absorbs energy, designed to minimize injury to pedestrians at impact speeds up to 15 mph. A further safety feature is the absence of distortion in the slightly curved windshield, and unobstructed frontal view provided the driver. The vehicle has also been designed to withstand rollover crashes at 70 mph by incorporating four rollbars supporting a reinforced, padded roof. The energy-absorbing doors provide occupant protection from 40-mph side crashes, and a rear bulkhead affords rear impact protection. The rear roll-down window is sloped out at the top to avoid being covered by snow or clouded by rain.

The interior contains miniaturized instruments, dash-mounted periscope screen and manual controls, a cushioned steering wheel, contoured seats with lateral supports and headrests, and an integrated harness and lap-belt restraint system. Entrance and exit is facilitated by a flip-top door with attached arm rest-hip support padding. The doors, with reflectorized zebra-striped edges, have a rotary latch as well as strong pins that engage the body structure.

THE NEW YORK STATE SAFETY CAR





Hovercrafts

The world's largest hovercraft, the SR.N4 of the British Hovercraft Corp., has just begun regular 30-mile crossings of the English Channel at speeds up to 70 mph, in seven round trips daily.

This 165-ton vessel carries over 600 passengers-- or 30 cars and 250 passengers. The 130-ft long, 75-ft wide craft is driven by four 19-ft propellers, mounted on pylons that can be swiveled 30% toward two huge air rudders for maneuverability. Power is provided by four 3,400-hp engines.

The hovercraft travels on a cushion of compressed air, confined by a 7-ft high nylon-and-rubber-tube skirt. The gliding passage over the water is described as "surprisingly smooth."

Containerships

This sea-freight system represents application of packaging technology, in which standardized, large-unit containers have been used in highway and rail transport of freight.

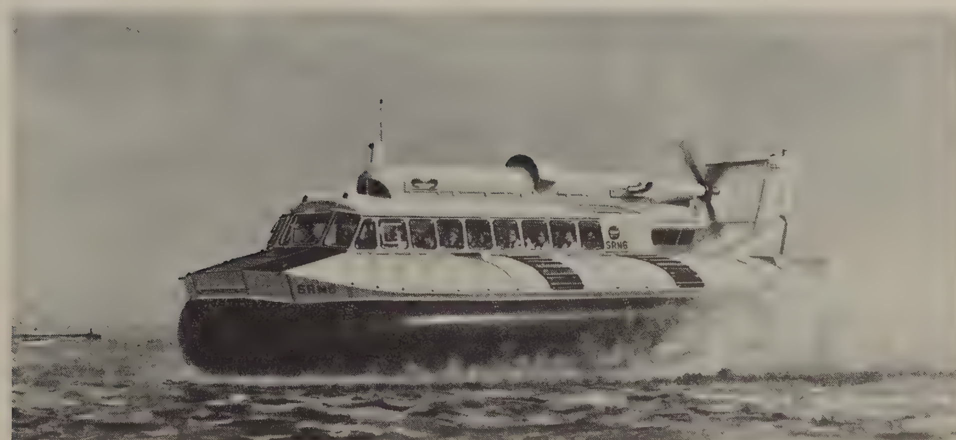
A containership recently launched by the Atlantic Container Line, Ltd., provides space for cars, trucks, trailers, buses, and construction equipment. These can be driven onto any of four auto decks that can accommodate 1,100 cars or onto two trailer decks. This system permits a trailer to be loaded at an inland city, and then driven to port and aboard ship. The agent for whom the trailer is destined drives it off at another port and delivers it to a destination that may also be inland. The trailer can then be reloaded with cargo and returned to the port for shipment, to another port, or returned to the original sender. The advantage of this system is the ease of loading and unloading.

Recently, in a demonstration, the Port of New York Authority used a Sikorsky "flying crane" helicopter to prove that a containership could be unloaded while anchored offshore. In the demonstration, containers weighing as much as 10 tons apiece were moved from the ship even though the wind was approximately 50 knots and the waves 6 ft high. This demonstration showed that ports lacking sufficient facilities to accommodate a containership could still be serviced. Also, in addition to expanding containership operations to undeveloped ports or to ports without facilities for containerships, a containership carrying its own helicopter could service small cities located short distances inland.

Prudential Lines and Pacific Far East Line have constructed ships using the "lighter-aboard-ship" concept. In essence, these ships use "lighters" which are loaded at the wharf and then come out to the mother-ship where they are lifted aboard by a gantry crane. When unloading, the lighter is lifted back into the water for its trip to shore. The ships are designed to carry lighters 62 ft in length.

WATER-ASSOCIATED VEHICLES

The Containership



BRH's Hovercraft

The Lykes Bros. Steamship Company is planning to acquire three-deck "sea-barge clippers" for its trips between the Gulf Coast and Europe. These ships will hold 38 barges, each 97-ft long. A stern elevator raises or lowers the barges and hydraulically operated, wheeled transporters are used to move each barge to its storage area.

Barges can be loaded in shallow draft ports, and on rivers and other inland waterways which are inaccessible to ocean going vessels, and then moved to a mother ship anchored offshore. Thus, it is possible to give every small town along major rivers and waterways the status of ocean-going ports. This also reduces the need for large warehouses at a port in which to collect cargo for shipment.

Hydrofoils

Development of hydrofoils for use in passenger conveyance has been promoted in Europe. The hydrofoil is a water vehicle with a boat-like hull which functions as a normal boat at slow speeds, but at high speeds lifts out of the water and is supported by small wings which at low speeds are submerged. As the hull lifts out of the water, hull drag is eliminated, making possible speeds of 50 to 90 mph.

In Italy a hydrofoil operates on Lake Garda di Senzano at a speed of 50 mph. In addition, a prototype Polish passenger hydrofoil for use in the Firth of Szczecin has been constructed. It was designed at the Gdansk Technical University and constructed by the Gdansk River Shipyard. This vessel can carry 76 passengers. Hydrofoils have been used successfully in Germany, Russia, and several other countries. During 1963-64, service from Manhattan and the Bronx to the New York World's Fair site was also provided by a hydrofoil.

Aquamotel

The "Aquamotel" has been developed by Cornell Aeonautical Laboratories as a modern application of packaging concepts to the car ferry, for passenger and auto travel by means of inland waterways.

Driving aboard at an embarkation point on a river, lake, or canal, the motorist enters a large, portable, cabin-parking cell. The passenger then has access to central shipboard dining and entertainment facilities, as well as private sleeping quarters. The passenger, auto, and cell containing them both, could be hoisted by crane and deposited at waterside motel buildings for brief or extended stays.

Long-Haul Aircraft

Larger, faster commercial passenger and cargo planes will soon be operating, necessitating extension of many airport runways to lengths of 2 miles or more. The Boeing 747 "Jumbo Jet" is a prime example of the larger new planes with both passenger and cargo capacities more than twice those available in planes currently operating. The Anglo-French supersonic Concorde and the Boeing 2707 SST, by the early 1970's, will halve present long-distance travel times.

V/STOL Aircraft

Future passenger transport to and from airlines terminals, and other short-to-medium range trips, are likely to be handled increasingly by V/STOL (vertical or short takeoff and landing) aircraft. Still in the development stage, they will eventually permit direct transport of up to 100 passengers to and from central city areas, without need for ground travel. V/STOL ports may be located atop tall buildings (as for example, on the Pan Am Building in Manhattan), and adjoining or over bodies of water.

Designs vary from the tilt-wing concept used by Vought-Hiller-Ryan, to the tilt-fan confuguration of McDonnell. Major benefits of these craft are their ability to land and takeoff in built-up areas as helicopters do today, and also travel on hauls of up to 500 miles between central cities at speeds of 400 to 500 mph. Their speeds and city-center-to-city-center flight capability should permit them to complement the high-speed trains now being developed, thus providing the traveler a choice of travel modes. Problems of noise and downblast will of course have to be taken into account, and research is underway on aircraft noise suppressors.

Helicopters

Development of family-sized helicopters has been given little major, prolonged attention in the past by industry. However, efforts are being made now by several firms to produce such aircraft. A recent example is the passenger helicopter developed by the Scheutzow Helicopter Corp. Its small size makes it suitable for commuter use between home and city-center VTOL-ports. Since much air travel is performed on a repetitive basis by businessmen, their using such vehicles to and from the airport would do much to relieve congestion on existing ground transport facilities.

Sky Lounges and Sky Cranes

In a major departure from current methods of passenger transport from the central city to the airport, the Los Angeles International Airport has been developing the concept of a flying bus. Termed a "Skylounge," it consists of a Sikorsky S-64 Flying Crane helicopter and a Budd Co. passenger module.

The bus-like vehicle would be towed on the ground through the central city where it would pickup aircraft passengers and their luggage at hotels and other central locations. The lounge would then be airlifted to the airport, and driven to the airline terminal. The present 12,000-lb demonstration model Skylounge can transport 23 passengers, and plans are underway to increase this to 43 passengers. Even greater passenger capacity exists today as demonstrated by the Russian MI-10 cargo helicopter which can handle 33,000-lb loads. The same Russian helicopter, when converted the MI-6 passenger aircraft, can transport 80 people.

TERMINALS

Transportation terminal problems confronting the traveler break down into familiar categories:

- Local travel to and from the terminal (whether by car, bus, rail transit, or small aircraft), with the associated problems of short and longer-term car storage.

- Passenger servicing within the terminal, including ticket processing and baggage handling.

- Passenger movement to and from planes or trains within the terminal.

The rail terminal is undergoing reevaluation in terms of operations and system functions, as a consequence of renewed interest in passenger service. Relationships of trains to other transportation modes are receiving special scrutiny, particularly in terms of taking greater advantage of traditional locations in centers of cities. The Journal Square Terminal in Jersey City is a current example of mixing or blending of travel modes, providing a genuine "transportation center" to accommodate rail, auto, and bus vehicles and passengers.

Because of passenger and baggage volumes, as well at its usual remoteness of location, the problems of the airlines terminal appear more severe and are receiving far more attention.

TERMINAL DESIGN INNOVATIONS

Rail-auto-bus intermodal mix (Journal Square, Jersey City)

Over-water runway extension (LaGuardia)

Satellite terminal with telescoping walkways (Kennedy)

Preponderant modes of current travel to and from the air terminal--car and bus--may be increasingly supplemented in the future by automated rail transit lines. At present only a few major airports are connected to central cities by such links--London and Brussels with conventional trains, and Tokyo with an 8.2-mile monorail. As noted previously, another solution is now provided in Cleveland, where a direct rail connection runs 19 miles from downtown to within 150 ft of the terminal building. This has been accomplished by extending the city's rapid transit system. The Rail-Bus, discussed earlier in this Appendix, is yet another experimental solution of the problem of getting swiftly to the airport.

Parking will be handled at the Los Angeles airport by 16 separate multi-level garages now under construction, none having a capacity over 2,000 cars. These are centrally oriented to six separate perimeter ticketing buildings, each serving a separate satellite air terminal. The local master plan calls for future underground parking beneath new underground terminal structures, as well as V/STOL ports atop aboveground parking structures for short hops downtown and other local flights. A corresponding landing pad is projected above a garage to be built over the tracks at the city's principal rail depot.

Experimentation in terminal design is ranging from one extreme, demonstrated by the 2-mile long "linear" or "spine" Dallas-Fort Worth terminal (consisting of ten connected "flow-through" unit buildings each containing seven specialized stories), to another extreme in the highly dispersed "satellite" terminal complex at Los Angeles. These and many other new terminals have in common great specialization of facilities for ticketing and baggage handling. In Los Angeles, passenger baggage is checked in at the parking area, with automated baggage movement to the planes by an adaptation of the Teletrans system previously discussed.

Passenger movement within the terminal, occasionally involving complete separation of arrival and departure flow, is being accomplished by a variety of means. These vary from moving sidewalks and escalators, to the mobile lounge vehicle from terminal to plane pioneered at Washington's Dulles International Airport, and the telescoping "snorkel" or "jetway" corridors from building to plane now in use at many major terminals.

Although in some instances, existing airports can be modified for newer, longer jet runways (even by extension of runways over water or on landfill), the trend is clearly to new construction on ever more remote rural sites. New airport design is complicated by requirements of forthcoming, larger-capacity SST aircraft, which will increase peak demand for passenger services as a result of greater passenger volume per flight.

Finally, in ship travel as well as air and rail service, new solutions are being sought for terminal problems. The Port of New York Authority has proposed a multi-million dollar terminal complex for ocean travelers. The intent is to provide the most

comfortable, efficient pier facilities anywhere. The terminal would provide berths for six vessels. Plans for each of three finger piers include areas for cargo and service functions, vehicles picking up or discharging passengers, baggage facilities, customs, passenger and visitor waiting rooms, short-term parking facilities, and a public park. In addition, the pier-connecting headhouse will have a heliport on the roof, serving those flying out of New York to other destinations by providing a quick means of transportation to major airports.

EQUIPMENT AND FACILITIES

Not all the massive effort of industry and government has been directed specifically toward developing vehicles for moving people and materials, or terminals for transfer between transportation modes. Substantial research also is continuing on supporting equipment and facilities necessary to provide and maintain an efficient total system. As a result, a broad array of ingenious devices, equipment, and facilities have emerged, a few of which are described here.

Automated Fare Collection

Under a 2/3 Federal grant of $181,426 provided by HUD, with the State of New York furnishing the remaining $90,714, the Long Island Railroad successfully conducted a 1-year demonstration project of an off-train automatic ticket collection system during 1964-1965. The system is based on the use of a magnetically encoded plastic commuting ticket purchased by the commuter in advance, and special turnstiles triggered by the tickets, thereby cancelling one ride. The time, station of origin, and destination are automatically transferred to a computerized record control center where train schedules are adjusted to meet varying demand. When all rides on a ticket are cancelled, the ticket is magnetically erased and re-encoded, giving it a virtually unlimited life. The system is in routine use by the Illinois Central Railroad in Chicago and the London subway, and will be installed in San Francisco's new BART rapid-transit system.

Long Island Railroad Electrification

This program calls for extension and rehabilitation of the Long Island Railroad's electrification system to permit maximum use of the new high-speed cars and to improve service in areas of rapidly expanding population. Additions to the third-rail system will total 16.1 miles, running from Mineola to Hicksville to Huntington. Estimated to cost $47 million, the electrification program is expected to be supported by a $23 million HUD capital grant.

East River Tunnel

The East River tunnels afford the Long Island Railroad its only direct access between Queens and Manhattan. These tunnels are pressed to capacity during peak travel hours and offer commuters only one terminal point in Manhattan. Moreover, by 1985 the Long Island Railroad will have to bring twice as many commuters into New York City. Accordingly, the MCTA has initiated a cooperative venture with the New York City Transit Authority to construct a joint use, double-decker rail tunnel across the East River -- the first such underwater facility in the nation. In August 1966, the two Authorities agreed on a joint subway-LIRR four-track tunnel from 63rd St. and York Ave. in Manhattan to 41st and Vernon Blvd. in Long Island City. Estimated to cost about $75 million, the tunnel will be financed half by city funds and half by MCTA. In 1967, the State Legislature approved a first instance advance of $37.5 million to MCTA for design and initial construction costs.

Automatic Railroad Car Identification

By means of an advanced-design electronic scanning device that can read identifying color-coded stripes on freight cars traveling up to 80 mph, any freight car in the country can be located instantaneously. The track-side scanner, whose operation is not influenced by adverse weather, relays the information into computers, which in turn are tied in with a centralized computer system connected to all railroads in the nation. For the first time, railroads will be able quickly to pinpoint locations of cars needed for seasonal or emergency conditions, supply shippers prompt and accurate information on enroute shipments, and provide an instantaneous industry inventory of every interchange freight car. It has been estimated that full implementation of the system could increase the use and efficiency of freight cars by as much as 10 percent of the nation's fleet, roughly equivalent to an additional 180,000 freight cars.

Automatic Track-Laying Machine

Costing more than $100,000, a new mobile track laying machine has been constructed by the Canadian National Railways. The highly automated unit is 105-ft long and weighs 55 tons. It runs on pneumatic tires over the railway roadbed, and can put down 1 mile of new track each day. It can travel under its

own power from one site to another. Moving at a steady rate of 1/10 mph, the machine fabricates a continuous section of track, complete with ties and fastenings, and drops it on the roadbed in its wake. Rail and track material are strategically placed along the right-of-way prior to the track layer's arrival. On the job, a large deck-mounted hydraulic crane lifts lengths of rail from the roadbed to slanted rollers on each side of the machine. The rails move along the unit under their own momentum, with the distance between rollers equal to the standard gauge of the track to be laid. The crane also lifts all other track material from the ground to storage bins on the machine. Sections of rail are then bolted together, and ties fastened with the addition of plates, spikes, and anchors.

Track Levelers

Performance of any wheeled vehicle that runs on tracks is directly related to how well the original track profile and alignment are maintained. As train speeds and payloads of increase, effective track maintenance becomes increasingly important. This, coupled with rising labor costs and the limited output possible with track repair crews, has prompted development of several types of track-riding equipment to accomplish many tasks efficiently and economically. Manned by a single operator, one version can lift and align a cross-tie and rails to the correct position on both straight and curved sections, tamp roadbed material to the desired elevation, and then replace the tie. Under normal conditions, 1000 ft of track can be serviced in an hour. Sophisticated variations include computerized controls, oscillograph recorders providing permanent records of track elevation and joint displacements, and direction-finding television camera/display systems.

Instrumentation Train

To minimize human judgment required in evaluating track conditions, the Southern Railroad has outfitted an electronic laboratory on wheels at a cost of $2 million. Converted from a business train, the car can be coupled to any passenger or freight train and operated at speeds up to 80 mph. Its 274,000-lb gross weight deflects track the same as revenue cars, thereby permitting measurements under normal loading conditions. Rail characteristics that can be monitored continuously and recorded include vertical unevenness of the rails, track warping or twisting, rail curvature, variations in distance between rails, and superelevation of the track. Future plans call for using the car to measure stresses or other parameters in components of cars to which it is coupled, drawbar pull, and other forces. Consideration also is being given to computerizing the large volume of data to facilitate interpretation in allocating maintenance.

AAR Research

Receiving financial support primarily from member railroad companies, the Association of American Railroads is continually engaged in many areas of rail-

road research. Headquartered in the Illinois Institute of Technology in Chicago, the Association's Technology Center is one of the largest and best equipped testing centers in the world. These facilities, coupled with full-scale tests on member lines, have produced a virtually endless stream of improvements and modifications to every component of the railroad system. Recently completed or active investigations include identification of acceptable roller bearing greases and center plate lubricants, improvement in hotbox performance, development of underframe impact cushioning devices, determination of the effect of heat treatment on static and dynamic performance of axles, modifications to braking equipment, evaluation of preservatives to prevent termite attack on wood ties, development of various packaging designs to prevent damage of cargo, stabilization of track roadbeds, structural requirements at pipeline crossings, effectiveness of cross-tie anti-splitting devices, welding procedures for heat-treated rail crossings, compilation of rail failure statistics, and instrumentation and testing of full-scale loaded bridges.

Infra-Red Bus

Under sponsorship of the New York State Department of Transportation, a study is underway to determine the feasibility of providing buses a means of controlling traffic lights in their favor. An infra-red device has been developed that will activate traffic signals as express buses approach. Conceivably, such a system might increase travel speeds on urban streets from 13 to 30 mph. The application may be restricted to less congested areas, and those without computer controlled signals.

Moving Sidewalks

Moving sidewalks have been used for the last 6 years to transport pedestrians up and down steep inclines in Tacoma, Washington. These "Speedramp" units, made by the Stephens-Adamson Manufacturing Co. consist of a 42-in. wide conveyor, upon which pedestrians are moved at a speed of 90 ft per minute. One "up" and one "down" unit are positioned side by side and are capable of moving 9,600 passengers each hour. Similar installations are operating in Toronto, Milwaukee, and San Diego.

The manufacturer has recently suggested an innovation to this system called "Carveyor," which would shuttle passengers between metropolitan districts and large parking lots located in urban fringe areas. This installation consists of a large conveyor similar to the Speedramp unit. However, in this case passengers would be moved along the conveyor at 15 mph in specially designed cars capable of accommodating 4 to 10 passengers. An interesting feature of this concept is that the cars would never stop moving. When approaching loading areas, the cars would be shunted to a slower moving belt, and passengers loaded and unloaded from a sidewalk moving at the same speed as the cars. Passengers would have little or no wait for seats, since an endless procession of cars would be available on the conveyor.